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A PROPOSED MODIFICATION TO REGULATION OF LAKE OKEECHOBEE

Paul J. Trimble and Jorge A. Marban
South Florida Water Management District,
3301 Gun Club Road,
West Palm Beach,
Florida 33416, USA.

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ABSTRACT

The current Lake Okeechobee regulation schedule is two feet higher than previous schedules that were in operation during the early 1970's. Its implementation was in response to prolonged periods of drought that occurred during the 1960's and early 1970's and the large increases in consumptive uses that were projected, and are presently occurring in south Florida. The additional storage provided by the schedule undoubtedly helped prevent more severe water shortages during the record setting 1980-1982 drought. However, two environmental concerns associated with the present schedule surfaced in recent years with the return to more normal rainfall conditions. First, the present schedule allows frequent high water conditions to exist in the lake that appear to be stressful to the unique littoral zone habitat of the lake. Second, the allowable buildup of storage prior to the dry season, combined with the large required decrease in storage prior to the hurricane (wet) season, contribute to the need for large regulation releases to tidewater. These large discharges have undesirable impacts on ecosystems of the downstream estuaries. This paper presents an alternative schedule that better meets the needs of the estuarine habitats without negatively impacting the other objectives of managing the lake.

(KEY TERMS: estuary ecosystems; flood protection; littoral zone habitat; regulation schedule; water supply; competing objectives.)

INTRODUCTION

Lake Okeechobee is the second largest freshwater lake lying wholly within the boundaries of the United States. Its location, in south central Florida, is illustrated in Figure 1. This body of water benefits south Florida by storing massive amounts of water during wet periods for subsequent withdrawals by agricultural and urban users during dry periods. However, south Florida's potential for heavy rains and severe tropical storms requires that water levels in the lake be carefully monitored to ensure that they do not rise to levels that would threaten the structural integrity of the levee system surrounding the lake. Therefore, when water levels in the lake reach certain elevations designated by the regulation schedule, discharges are made through the major outlets to control excessive buildup of water in the lake. The timing and magnitude of these releases is not only important for preserving the flood protection of the region, but also for protecting the natural habitats of Lake Okeechobee's littoral zone and the estuaries downstream of two major outlets. Extended periods of high water levels in the lake are apparently stressful to the lake's littoral zone habitat, while frequent large discharges to the estuaries cause undesirable changes to the ecosystems existing within them.

In summary, the competing objectives associated with managing the lake water levels are:

1. Provide adequate flood protection for the regions surrounding the lake.

2. Meet the water use requirements of the agricultural and urban areas dependent on Lake Okeechobee for water supply.

3. Preserve the biological integrity of the estuaries downstream of the lake's two major outlets to the ocean.

4. Preserve and enhance the lake's littoral zone which provides a natural habitat for fish and wildlife.

The current regulation schedule that is employed to manage the lake water levels is illustrated in Figure 2. This schedule contains three zones. When the lake stage is in Zone C, releases are made only for water use purposes. In Zone B, regulation releases are begun but are limited to a percentage of the maximum capacity of the outlets. Once the stage enters Zone A, maximum regulatory releases are made through the major outlets for flood protection purposes.

The extreme rainfall pattern in Florida during the 1980's has brought to focus many issues that are affected by Lake Okeechobee's regulation schedule. In this report an alternative regulation schedule that is more effective in preserving the biological integrity of the estuaries downstream of the lakes' two major outlets to the ocean without significantly altering the ability to meet the other objectives of managing lake water levels is presented. These findings are a result of a detailed analysis of the Lake Okeechobee Regulation Schedule by Trimble and Marban (1988).

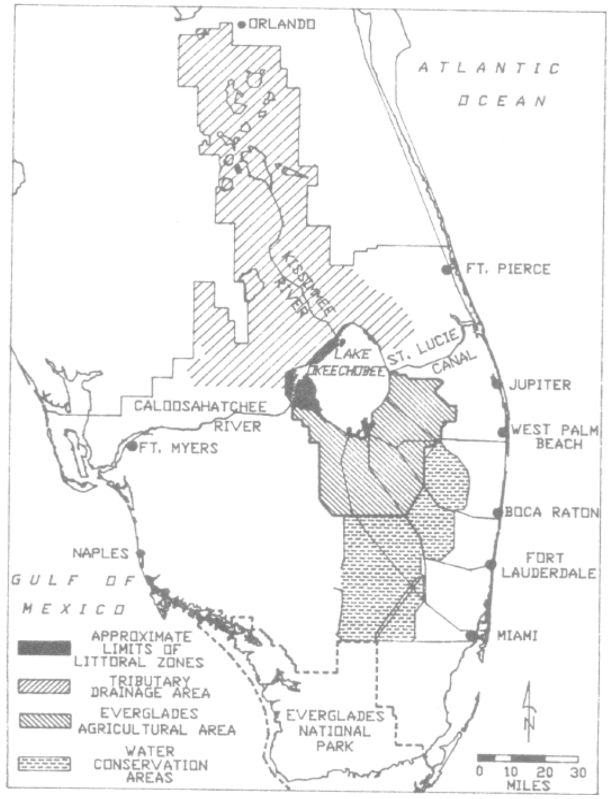
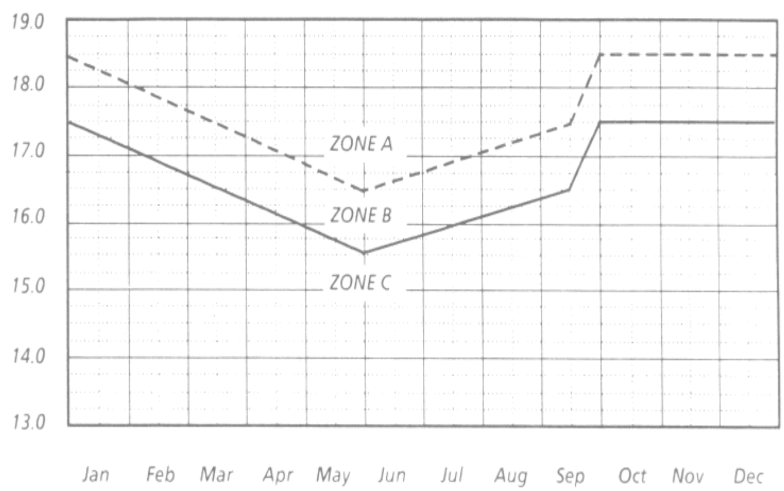


Figure 1. Location of Lake Okeechobee within the South Florida Water Management District.

MULTIOBJECTIVE PURPOSE OF THE REGULATION SCHEDULE

Preserve Littoral Zone Habitat

Lake Okeechobee is a large, shallow, freshwater lake that covers an area of approximately 450,000 acres. It is enclosed by a system of levees built for the purpose of providing flood protection and increasing water supply. Water levels average about 14 feet (msl), and range between 10 and 19 feet (msl). The bottom of the lake is approximately at mean sea level near the center. Along the outer edge of the lake the bottom rises to about 15 feet (msl) at which height it intersects the enclosing levee system. The regions in which the bottom ranges between 10 and 15 feet contain emergent marshes that are a valuable habitat for many species of wildlife. These regions are illustrated in Figure 1. Long periods of flooding of these marshes may be harmful to the littoral zone habitat that needs periodic drying. The distribution of major plant communities within the Lake Okeechobee littoral zone was first documented in 1972-1973 (Pesnell and Brown, 1977). After the regulation schedule was raised from 13.5-15.5 feet (msl) to 15.5-17.5 feet (msl) in 1978, lake stages subsequently increased. Substantial changes in the composition and distribution of plant communities were recorded in 1981 (Milleson, 1987). The most apparent were the near elimination of Spikerush (Eleocharis cellulosa) community, expansion of the cattail zone (Trypha domingensis), and domination of the mixed grass zone by torpedo grass (Panicum repens). Although many of these changes reversed themselves during the severe 1981-1982 drought, the continued adherence to the 15.5-17.5 It (msl) schedule has the potential to lead to a decline in the diversity of the littoral zone plant community. The more water tolerant species will be favored. The long term tolerance of spikerush and beakrush is 2 to 3 years with two feet inundation (Givens, 1956). These extensive communities provide a considerable percentage of the feeding habitat for the wading bird population dependent on Lake Okeechobee. The willow community, which has a five year tolerance to inundation of 2 feet of water, provided the principal nesting place for wading birds. These findings are documented in a report completed by the South Florida Water Management District (Zaffke, 1984). Whether low water levels naturally occur frequently enough for the plant communities to experience the periodic drying required for their existence is still under investigation. Further data collection and analysis is needed to resolve this issue. Until this effort is completed, it is important that any interim regulation schedule put in operation does not increase the period of inundation of the littoral zone. Any action to lower the lake regulation schedule would have to be evaluated from a multiobjective perspective including its effects on water supply.



Releases Through Major Outlets for Current Schedule

Zone	Agricultural Canals	Caloosahatchee River	St. Lucie Canal
A	Pump maximum practicable to conservation areas for regulation after removal of local runoff	Up to maximum capacity (9300 cfs at S-77) without local flooding	Up to maximum discharge at S-308C
B *	(same as above)	Up to 4500 cfs at S-77	Up to 2500 cfs at S-80 **
C	No regulatory discharge	No regulatory discharge	No regulatory discharge
	FIRST PRIORITY	SECOND PRIORITY	THIRD PRIORITY

* Releases through various outlets may be modified to minimize damages or obtain additional benefits.

** Except when exceeded by local inflow

Figure 2. Present Lake Okeechobee Regulation Schedule

Provide Water Supply

Immediately south of Lake Okeechobee is the most highly developed agricultural area of south Florida This area includes nearly 700,000 acres of intensely farmed agricultural land that was originally part of the Everglades wilderness wetlands until being drained with the dredging of four major canals in the early part of the century. During dry periods, these canals also serve as a means for delivering water from the lake to the Everglades Agricultural Area (EAA), and to the densely populated areas of the lower east coast of Florida including Miami, Fort Lauderdale, and West Palm Beach. During the early 1960's the Water Conservation Areas (WCA) were built to provide additional surface water storage for the lower east coast urban areas and the Everglades National Park. They are located south of the EAA, north of the Everglades National Park, and to the west of the coastal urban areas (Figure 1). These areas normally supply significant quantities of water during the early months of a drought. However, during extended drought periods these shallow bodies of water often dry out leaving the Everglades National Park and the lower east coast urban areas dependent on Lake Okeechobee for water supply. The climate of south Florida allows for continuous agricultural productivity (throughout the year). Hot humid tropical air dominates the region during the period of June through October (wet season). During this period, rainfall from local convective activity and tropical disturbances normally supply sufficient rainfall for agricultural and municipal needs. Occasionally some supplemental water may be required from the lake. The period of November through May (dry season) is dominated by mild dry air. Agricultural and municipal regions in south Florida dependent on the lake as a primary or secondary source of water supply normally require it during this period. Dry season losses in storage due to evapotranspiration and water use have been as large as 2 million acre feet, corresponding to a drop in stage of over 4 feet. The most serious situations arise during multiseasonal droughts when less than normal wet season rainfall occurs prior to the dry season. The drought of 1980-1982 was the worst drought on record. In the interior sections of Florida, this drought has a return frequency of occurrence of less than a 200 year drought (Lin, et al., 1984). Water levels during this drought fell from the present maximum allowable regulation stage of 15.5 feet (msl) on May 31, 1980, to a record low stage of 9.75 feet (msl) on July 31, 1981. Available storage for water use is nearly depleted at that stage. Water levels remained dangerously low through May 1982. Generally, the present schedule allows for an ample supply of water to be stored in the lake during wet periods for use during dry periods. The fact that this schedule was in effect during the 1980-1982 drought prevented significant economic losses during this drought period.

Minimize the Impacts to the Downstream Estuaries

The tributary drainage area to the north of Lake Okeechobee, which includes Fisheating Creek, Lake Istokpoga and its tributaries, the Kissimmee River basin, Taylor Creek, and Nubbin Slough is over 3 million acres (shaded area in Figure 1). Historical net gains in storage in the lake due to runoff from this large area along with direct rainfall on the lake have been as large as 1.6 million acre feet per month and up to 4.8 million acre feet for one year. Average annual net storage gains are about 1.1 million acre feet. Prior to the period of regulation of the lake and the drainage of the Everglades region south of the lake, the majority of large inflows would slowly flow southward into the Everglades and eventually be lost to evapotranspiration. Another portion of the water would flow slowly through the marshlands on the western edge of the lake and enter the Caloosahatchee River which eventually empties into the Gulf of Mexico, but there was no direct path for the water to flow from the lake to the St. Lucie estuary on the east coast of Florida. With the dredging of the St. Lucie Canal, and the deepening and extension of the Caloosahatchee River, these outlets become the major route for excess inflows that enter the lake. Water could no longer flow naturally southward into the Everglades as a levee now encircled the lake. Regulatory discharges, at times, may be made southward through the drainage canals south of the lake, but this outflow is limited due to local runoff in the Everglades Agricultural Area. The St. Lucie Canal and the Caloosahatchee River empty into estuaries that are sensitive to the magnitude and timing of freshwater releases that are made into them. The design capacity of the Caloosahatchee River is 9,300 cubic feet per second (cfs), while the St. Lucie Canal has a design capacity of 11,000 cfs. Haunert and Startzman (1985) found significant changes to the St. Lucie estuary as a result of flow as low as 2,500 cfs for a period as short as three weeks. This experimental 2500 cfs discharge increased the zone in which salinities ranged from 0.5 to 5.0 parts per thousand (ppt) from a small portion of the inner estuary to a large portion of the middle estuary and induced changes to the middle estuary biological communities. Subsequent numerical modeling studies (Morris, 1987) indicated that, if the discharges had continued for another 10 days, the inner and middle estuary would become fresh water and would threaten the survival of existing oyster reef communities. Previous regulatory releases have been large and long enough to create fresh water conditions in the estuaries for extended periods. The loss of oysters decreases the carrying capacities of the system since these organisms provide a food source and habitat for other organisms. Extended periods of larger releases to the estuary would significantly alter salinities of the outer estuary. These salinity changes would likely have drastic effects on the diverse populations of estuarine and marine benthos and fish.

The larger the releases, the greater the potential to upset the delicate balance of the estuary. At times regulatory releases must be made. This study proposes a schedule which minimizes the effects of the regulatory releases not only by minimizing the largest Zone A releases but also by beginning very small releases earlier and in a more natural manner. This is accomplished without negatively affecting the other major objectives of managing the lake.

Provide Adequate Flood Protection for the Region

The regions adjacent to the lake have a potential for severe damage and loss of life if the lake's levee system were overtopped by wind driven surges. This situation is very unlikely under the present regulation schedule and it is of utmost importance that any newly proposed schedule maintain the same level of flood protection that currently exists. With the St. Lucie Canal and the Caloosahatchee River having such large discharge capacities, water levels would rarely reach 19 feet (msl) under the present operational schedule. The levee system sur- rounding Lake Okeechobee ranges between 32 to 45 feet (msl); therefore, the likelihood of overtopping the levees from having excess storage is almost nonexistent. However, large surges of water caused by sustained hurricane force winds could overtop the levees under specific conditions. A sustained hurricane force wind of 100 mph with an average lake depth of 18.5 feet may cause the water level to rise up to 35 feet (msl) on the downwind side of the lake. To maintain the same level of flood protection for the region surrounding Lake Okeechobee, it is important that lake stages during the peak of the hurricane season (August, September, and October) not exceed what they would be with the present lake schedule in effect. Atmospheric conditions are not as favorable for hurricane development during other months of the year when the frequency and severity of the storms is significantly less. During the dry season the only limitation on the lake level related to flood protection is that it should not be allowed to rise so high that it could not be brought down to safe levels by the time the hurricane season begins. Therefore, it may be possible to delay maximum discharges in the late winter and early spring months provided that water levels could still be brought to safe levels by the beginning of the peak hurricane season.

METHODOLOGY

The South Florida Regional Routing Model (Trimble, 1986) was used to test alternative regulation schedules in the multiobjective management of Lake Okeechobee. This model uses a mass balance approach for estimating water levels and discharges for Lake Okeechobee. Assumptions included in the model simulations were:

- Present day operational policies for the Everglades Agricultural Area and Water Conservation Areas to the south of the lake.
- Present day water use requirements for regions dependent on the lake for water supply were estimated as a function of historical rainfall conditions.
- Present day conveyance capabilities were available for making discharges between regions.
- Historical rainfall conditions that occurred between 1952 and 1984 would occur with the proposed schedules in operation.

The following four evaluation criteria or objective functions were chosen to summarize the multiobjective performance of each schedule.

1. The ability to satisfy the flood control criteria was measured by the mean and maximum September 1 lake levels reached during the study period. It is desirable that the levels reached with the alternative schedules in effect not exceed those with the present schedule in operation during this period when potential for heavy rains and large storm surge exist.

2. The objective of meeting water supply needs was measured by the amount of demands met during the study period. The performance during the individual drought periods were also considered and evaluated in this study. The most severe drought of the period was the 1980-1982 drought. The Lake Okeechobee stage fell to a record low level

of 9.75 feet (msl) during this period. Other critical years include the 1956, 1962, 1971, and 1974 low water levels periods within the lake.

3. The objective of protecting the estuaries was measured by the ability to reduce the number of days of Zone A (maximum) discharges during the study period. Although Zone B (Moderate) discharges have some negative impact on the estuary, Zone A discharges are very harmful to the estuarine habitat (Haunert, in prep.)

4. The objective of protecting the littoral zone habitat was measured by the percentage of days the simulated lake levels were below 15 feet (msl) during this study period. Extended periods of high water levels are undesirable for the littoral zone. It is, therefore, important to minimize the frequency of high stages.

The degree to which each of the alternative schedules satisfy the competing objectives of managing Lake Okeechobee is illustrated by plotting the schedules against each other. The method of comparison uses four orthogonal axes. Each axis represents one of the four major objectives being analyzed. In this case, a single schedule is represented by a box plot which connects the lines passing perpendicularly through each axes at the values simulated with that alternative schedule in effect. The axes are defined such that any schedule that meets a particular objective better than the current schedule will be plotted closer to the origin that the line plotted representing the current schedule, a schedule that satisfies all the management objectives better will be plotted entirely within the box formed by the results of the model with the current schedule in operation. Figure 3 represents the plot of the current schedule on this type of coordinate system.

STUDY PERIOD

The hydrologic period from 1952 through 1984 was chosen as the study period because the data set for this period contained highly reliable daily data and adequately represented the extremes of flood and drought condition that occurred to Lake Okeechobee during this century. Data for periods prior to 1952 back to 1913 is available from the Rule Curves and Key Operating Master Regulation Manual. However, these data were estimated by many different methods as the hydrologic system was changing and is not as reliable as more recent measured data. The 1952-1984 study period included the year with the largest (1960), the third largest (1959), and the fifth largest (1953) net storage gains for the period of record from 1915 to 1984. Two of these years, 1959 and 1960, occurred consecutively and the period from 1957 to 1960 included the largest four year net gain in storage for the lake for any period that records were available. On the other extreme, the extended droughts of the early 1960's, 1970's, and 1980's were unprecedented. During July 1981, Lake Okeechobee reached an all time record low water level; however, by the fall of 1982 and the spring of 1983, large releases were required to the ocean for flood protection causing concern for the natural habitats of both downstream estuaries. Prior to 1952 there was only one severe period of drought on record which occurred in 1945.

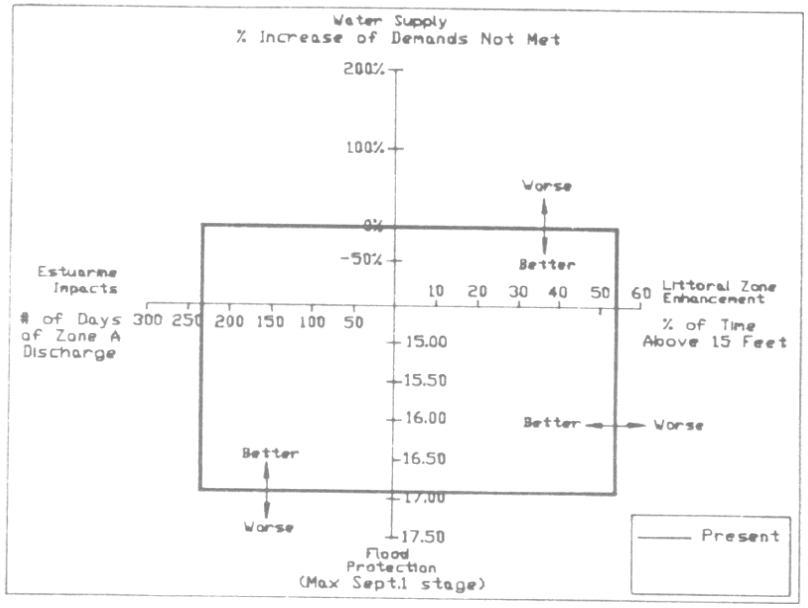


Figure 3. Tradeoff Comparing Four Management Objectives

RESULTS

Over 100 regulation schedules were modeled to test their effectiveness in meeting the objectives of managing Lake Okeechobee water levels and discharges. The results of 30 schedules are included in the Preliminary Evaluation of the Lake Okeechobee Regulation Schedule (Trimble and Marban, 1988). The results presented in this report are those of a schedule which reduces undesirable large discharges to the estuaries without;t negatively impacting the ability to meet the other objectives of managing the lake. Additional regulation schedules were tested which would enhance the littoral zone ecosystem, but they had negative impacts on the ability of the lake to supply water during drought.

Reducing the Impacts to the Estuaries

A major concern with the present regulation schedule is the allowable large buildup of storage during the fall and early winter months which may call for large regulatory releases of water during the late winter and spring months. Between January 1 and June 1 storage may have to be reduced as much as 900,000 acre feet in the lake. Figure 4 illustrates that historically only 5 out of 32 years had losses due to evapotranspiration and water usage significantly greater than 900,000 acre feet. During the other 27 years, substantial regulatory releases would have been required to lower the lake by 2 feet if it was near schedule on January 1. Although limiting maximum capacity (Zone A) releases to the estuaries is the principal objective for protecting the estuaries, Zone B discharges as defined by the present schedule (Figure 2) also have undesirable impacts on the estuaries (Haunert and Startzman, 1985).

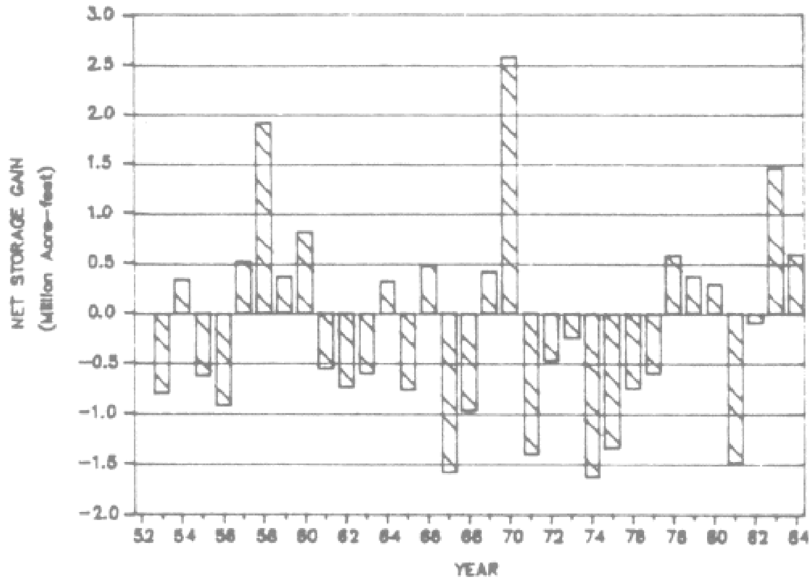


Figure 4. Historical Dry Season Storage Change

Numerical simulations (Morris, 1987) in conjunction with biological studies (Haunert, 1987) of the St. Lucie estuary were conducted by the South Florida Water Management District (SFWMD). These studies determined the levels of discharges through the St. Lucie Canal into the estuary that could occur with minimal environmental impact. Similar estimates were made for the Caloosahatchee estuary. The allowable discharges were incorporated into the South Florida Regional Routing Model (Trimble, 1986). These low flow releases were made at elevations below the existing schedule in an effort to reduce the fall and winter buildup of storage in a manner that would minimize the impacts to the estuaries. The most recent research from the SFWMD indicates that these low flow releases should simulate natural stormwater runoff which occurs in a pulsing dis- charge manner. Daily distribution of flows for a single pulse through the Caloosahatchee River and the St. Lucie Canal appear in Table 1. In order to estimate the proper width of the low impact discharge zone, a sensitivity analysis was completed to determine a zone that will not jeopardize the water supply stored in the lake, and at the same time, will minimize the risk of high regulatory releases to the St. Lucie and Caloosahatchee estuaries. Actual discharges that are made in this new zone are dependent on water conditions and the weather forecast throughout other portions of south Florida. For example, if the water levels in the tributary drainage area are low, water use to the south was high and if no rain was forecast, it may not be advisable to make any releases to the estuaries unless salinity conditions within the estuaries required such freshwater releases.

Table 1. Daily Flow Distribution for a Single Pulse

	St. Lucie Estuary (cfs)	Caloosahatchee Estuary (cfs)
Day 1	1200	1000
Day 2	1600	2800
Day 3	1400	3300
Day 4	1000	2400
Day 5	700	2000
Day 6	600	1500
Day 7	400	1200
Day 8	400	800
Day 9	0	500
Day 10-	0	500

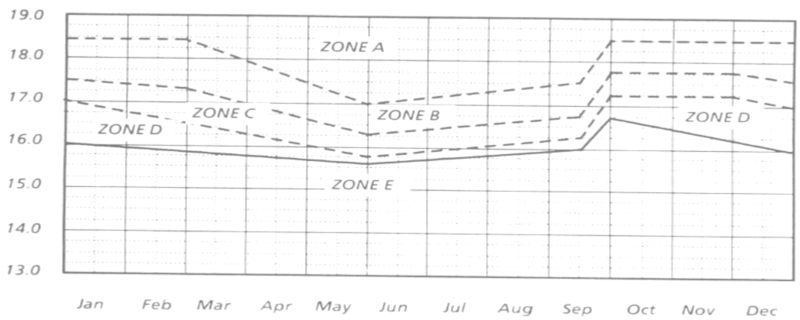
Other useful modifications to the current schedule that will help protect the estuarine ecosystems are:

1. Begin current Zone B level releases at lower stages during the winter and early spring months.

2. Introduce an additional new zone of moderate releases (3500 cfs) larger than the Zone B releases of the present regulation schedule, but considerably less than the Zone A releases. These releases will not cause undesirable sediment transport in the estuaries.

3. Delay Zone A releases in the winter and spring until higher stages are reached. This may safely be accomplished since storm surges and heavy rains associated with tropical storms do not occur during this period. Historical gains in storage during April and May for the period 1913 to 1987 are all much smaller than the outlet capacity of the lake. Therefore, the lake may still be able to be brought down to safe levels during these months prior to the hurricane season.

It was also found that delaying regulatory releases during late May is often beneficial for water supply availability during the following months, particulariy if below normal rainfall occurs during the normally wetter summer months. The alternative schedule appears in Figure 5.



Releases Through Major Outlets Using Five Zones Concept

Zone	Agricultural Canals	Caloosahatchee River	St. Lucie Canal
A	Pump maximum practicable to WCAs	Up to maximum capacity at S-77	Up to maximum capacity at S-80
B	Maximum practicable to WCAs	6500 cfs	3500 cfs
C	Maximum practicable to WCAs	4500 cfs	2500 cfs
D	Maximum practicable to WCAs	Maximum non-harmful discharges to estuary when stage is rising	Maximum non-harmful discharges to estuary when stage is rising
E	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE

Figure 5. Alternative Regulation Schedule

The tradeoff analysis between this alternative five zone schedule and the one that is presently in operation is illustrated in Figure 6. The number of days of maximum discharges to the estuaries is greatly decreased while some improvement is made for flood protection. This schedule has the potential of helping the estuaries significantly while not negatively impacting the other objectives of managing the lake; however, improvements for the littoral zone habitat were not significant.

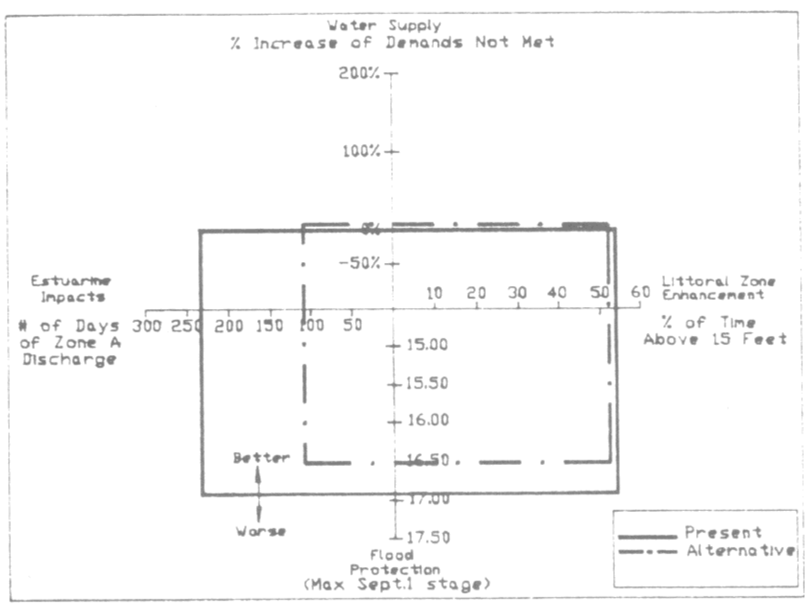


Figure 6. Comparison of the Present and Alternative Schedules

CONCLUSIONS

It has been determined from a sensitivity analysis using the South Florida Regional Routing Model with its estimations of regional water levels, discharges, and theoretical water use levels that a regulation schedule does exist that would greatly benefit the downstream estuaries of Lake Okeechobee without significantly affecting the other objectives of managing the lake. It still needs to be determined at what frequency high water levels become critical to the survival of certain species within the littoral zone and at what point water shortages may cause significant crop losses. The South Florida Water Management District is presently evaluating these issues. Consideration is being given to the implementation of an interim regulation schedule which minimizes the impacts to the estuaries from the large regulatory discharges, without adversely affecting the existing level of flood protection, water supply, or environmental enhancement.

ACKNOWLEDGEMENTS

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